PB88-220694

Automation of the Resistivity Measurement for Fly Ash

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Prepared for

Environmental Protection Agency
Research Triangle Park, NC

Jun 88

U.S. Department of Commerce
National Technical Information Service
NTIS

PB88-220694

EPA/600/D-88/131
June 1988

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EPA Contract 68-02-3988

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U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA/600/D-88/131	2.
3. RECIPIENT'S ACCESSION NO. PB88-220694/AS	
4. TITLE AND SUBTITLE: Automation of the Resistivity Measurement for Fly Ash	5. REPORT DATE: June 1988
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S): S. L. Nolen and G. H. Ramsey (EPA), and D. E. Elliott (Acurex)	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Acurex Corporation, Research Triangle Park, North Carolina 27713	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO.: 68-02-3988
12. SPONSORING AGENCY NAME AND ADDRESS: EPA, Office of Research and Development, Air and Energy Engineering Research Laboratory, Research Triangle Park, NC 27711	13. TYPE OF REPORT AND PERIOD COVERED: Published paper; 5/88
	14. SPONSORING AGENCY CODE: EPA/600/13

15. SUPPLEMENTARY NOTES: AEERL project officer is Sharon L. Nolen, Mail Drop 62; 919/541-7607.

16. ABSTRACT: The article describes the automation of the resistivity measurement for fly ash. Fly ash resistivity is an important consideration in the operation of particulate control devices based on electrostatic principles (the higher the resistivity of the fly ash, the more difficult it is to collect). Because of the need for characterization of fly ash resistivity and the large amount of time required to conduct the manual test, it was decided to automate the test. A standard (STD) bus computer was used in the automated test to monitor the temperature, collect current readings, and transfer the data to a personal computer. The personal computer was programmed to calculate and plot the results from the data received from the STD computer. The automated system tracks the manual system closely. It also consistently produces smoother curves and is very precise for duplicate runs. Most importantly, operator time for the test was reduced from about 6.5 hours per test to about 1 hour, thereby improving productivity.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution Fly Ash Electrical Resistivity Measurement Automation Computers	Pollution Control Stationary Sources Personel Computers	13B 21B 20C 14G 13H 09B

18. DISTRIBUTION STATEMENT: Release to Public	19. SECURITY CLASS (This Report): Unclassified	21. NO. OF PAGES: 13
	20. SECURITY CLASS (This page): Unclassified	22. PRICE: NO3 12.95

EPA Form 2220-1 (9-73)

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ABSTRACT

The resistivity of fly ash is an important consideration in the operation of particulate control devices based on electrostatic principles. The higher the resistivity of the fly ash, the more difficult it is to collect. Because of the need for characterization of fly ash resistivity and the large amount of time required to conduct the manual test, it was decided to automate the test.

A standard (STD) bus computer was used in the automated test to monitor the temperature, collect current readings, and transfer the data to a personal computer. The personal computer was programmed to calculate and plot the results from the data received from the STD bus computer.

The automated system was found to closely track the manual system. It was also found to produce consistently smoother curves and proved very precise for duplicate runs. Most importantly, the operator time for the test was reduced from about 6.5 hours per test to approximately 1 hour per test, thereby improving productivity.

INTRODUCTION

The resistivity of fly ash is an important consideration in the operation of particulate control devices based on electrostatic principles. The higher the resistivity of the fly ash, the more difficult it is to collect with conventional electrostatic precipitators (ESPs). The same kind of effect was found for the newer particulate removal technology, electrostatically enhanced fabric filtration (ESFF), developed by EPA's Air and Energy Engineering Research Laboratory (AEERL). Hovis et al.(1) found the resistivity of the fly ash to be an important parameter in the performance of ESFF.

The authors were asked to automate the dust resistivity measurement for several reasons. The measurement serves as an indicator in selection of a particular fly ash for a specific test and as a guideline for setting operation parameters for the particulate control devices. The measurements were also used to investigate and possibly explain unexpected results in tests of the control equipment. Based on these measurements, AEERL was able to predict the performance of the particulate control devices in advance.

Although AEERL had the capabilities to perform the test manually, it required a prohibitive amount of a technician's time to run the test for routine resistivity measurements. The objectives for automation were to decrease the time required to run the test and minimize potential operator interferences.

MANUAL TEST EQUIPMENT DESCRIPTION

A diagram of the equipment used for the manual test for determination of fly ash resistivity is shown in Figure 1. The equipment was

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developed for AEERL by Southern Research Institute and is described by Bickelhaupt (2, 3). The apparatus consists of four sample cells in an oven, a variable voltage power supply to apply voltage to the samples, an electrometer set to measure current, and a thermocouple for temperature measurement. A glass bell jar provides a conditioned environment for the sample cells.

A diagram of the sample cell is shown in Figure 2 along with the dimensions used in the calculation of resistivity given below. Various sample cell sizes may be used. In this particular cell, D = 2.54 cm and t = 0.53 cm.

MANUAL TEST PROCEDURE

The procedure used is an alternate method to the IEEE Standard 548-1984 (4) for determination of fly ash resistivity. This alternate method was developed by AEERL. It is applicable to the measurement and reporting of fly ash resistivity data and it applies to all fly ashes produced from the burning of coal and to other dusts that may be collected in an ESP. The dust resistivity measuring system may also be utilized to obtain data on the resistivity versus electric field of fly ashes and other dusts that may be collected in an ESP.

The method used in the dust resistivity measurement apparatus allows the resistivity curves to be calculated for fly ashes over a range of temperatures and humidities. Up to four samples of the same or different fly ashes can be tested at the same time. The procedure requires 2 days. The first day, the fly ash is placed in the sample cells in order to obtain a specified ash layer thickness. The loaded cells are then placed in a grounded environmental chamber on an alumina support and all electrical connections are made. The bell jar is then sufficiently sealed to maintain about 1 inch (2.5 centimeters) of positive water pressure when the gas is introduced. The oven is closed and heated to 450°C overnight.

On the second day, either dry or conditioned air from the water bath of known moisture percentage is passed through the chamber for approximately 1 hour without interruption of the ongoing procedure. The oven is then turned off allowing the test cells to cool by convection. For about every 30°C decrease in temperature a data point is established.

After the data have been recorded, the resistivities are calculated using:

$$\rho = (A/t) * R$$

where ρ = volume resistivity in ohm-centimeters
A = area in square centimeters

t = average thickness of the specimen in centimeters
R = measured volume resistance in ohms (Calculate from Ohms Law)

The resistivities are plotted versus 1000 times the inverse of the temperature in degrees Kelvin. The length of time required for the manual test is about 6.5 hours of operator time including sample preparation, calculations, and plotting.

AUTOMATED TEST EQUIPMENT DESCRIPTION

The basic configuration of the system remained unchanged after automation and the capability of running the test in the manual mode was retained. An autoranging picoammeter was substituted for the electrometer that was used in the manual test, and connections were made from it to all four sample cells. A standard (STD) bus computer was added to control and monitor both the picoammeter and the thermocouple for automation of the test.

The STD bus computer consists of four boards. The CPU board contains the microcomputer, the read only memory (ROM), and part of the random access memory (RAM). A memory expansion board with additional RAM was added to provide sufficient memory for storage of the acquired data. A reed relay board is used to connect either the thermocouple or one of the four current leads to the picoammeter. The four sample cells are floating and are connected to ground through the picoammeter. A digital I/O board acts to interface the STD bus computer to the picoammeter and to the personal computer used for calculation and plotting of the data.

The STD bus computer was programmed in machine language to perform the required functions for automation of the test. It begins the test when signaled by the operator. During the test, it monitors the temperature and acquires current readings for each sample at the beginning and end of the test and for each 10 degree decrement in between, along with the corresponding temperature reading. The reed relay for each sample cell is closed one at a time when a reading is to be taken. After a short delay to allow the current to stabilize, the current is read, and the reed relay is opened. The STD bus computer is programmed to end the test at a preset temperature or at a signal from the operator. The data remain stored in the STD bus computer until the operator returns and begins the process to transfer the data via an RS-232 cable to a personal computer for calculation and plotting.

Software was written for a TRS-80 Model III computer to receive the data from the STD bus computer, calculate the resistivities, and plot the resulting data. All software for this computer was written in BASIC and is interactive and menu-driven. The data are transferred by choosing the appropriate selection from the main menu. After the data are transferred, the second option, calculation of data, is chosen. The operator can choose to accept the defaults given for voltage, number of samples, and the sample thickness or input new values. The raw data and the data for each sample are saved in files corresponding to the date of the test and, in the case of the calculated data, the corresponding sample number. Once all the data have been stored on disc, the third option may be chosen to produce a plot of resistivity versus 1000 times the inverse of the temperature.

The attention required from the operator is minimal for the automated test. Test preparations remain the same as for the manual test and consist of preparing the samples and setting the temperature and moisture levels for the

heated chamber, requiring about 30 minutes of the operator's time. However, after initiating the test with the STD bus computer, no further attention is required until the conclusion of the test. After all data are acquired, the transfer of the data, calculations, and plotting can be completed in about 30 minutes. Therefore, the total operator time required to run the test has been reduced from about 6.5 hours to approximately 1 hour.

For some fly ashes, the current density may be too high or electrical breakdown of the dust may occur. This situation is obvious from inspection of the data. In these cases, the voltage is adjusted and the test is run again or the test is run manually.

TEST OF THE AUTOMATED SYSTEM

To test the automated system, two fly ashes were chosen that exhibited quite different resistivities. Resistivities were determined manually and using the automated system for each of the three samples at three different test chamber moisture levels: 5, 10, and 15 volume percent. In all cases, the automated system was found to track the manual system closely. It also appeared to produce consistently smoother curves than the manual system, reflecting the greater number of data points collected and perhaps indicating some operator influence on the manual measurements.

A typical comparison between the automated and manual systems is shown in Figure 3. The eight automated data points were interpolated to be shown at the same temperatures as the manual data points were taken for better comparison of the systems. Figure 3 shows the resistivity curves for fly ash No. 1 determined both manually and by the automated system for the 5% and 15% moisture levels. The resistivity shows a decrease with increase in moisture as expected. The anomalous data points in the manual test data at 5% moisture are probably due to operator error. This figure illustrates the type of human error the automated system was designed to eliminate.

The automated system was also tested to ensure precision. The same fly ashes used for the comparison between the automated and manual systems were used for this test. The system was found to be very precise for duplicate runs of the same fly ash sample. A typical result of duplicate runs is shown in Figure 4.

The accuracy of the manual measurement technique has been verified using standard materials and comparing the results with independent laboratories. Therefore, since the automated system was found to closely duplicate the manual system, the accuracy was assumed to be satisfactory.

CONCLUSIONS

The automated system has been in use for over a year and has consistently produced results comparable to those obtained manually. The resistivity curves produced by the automated system appear consistently smoother than those obtained manually, reflecting the greater number of data points collected and perhaps indicating some operator influence on the manual measurements. In addition, the automated system has eliminated human error from the calculation and plotting of the data. The data are conveniently saved on floppy disc in both raw and calculated form for future use. Finally,

the operator time required for the determination of resistivity has been reduced from about 6.5 hours per test to approximately 1 hour per test, thereby improving productivity.

ACKNOWLEDGMENT

The authors wish to express their appreciation to Norman Plaks, Leslie E. Sparks, Richard E. Ogan, and D. Bruce Harris of AEERL for their assistance.

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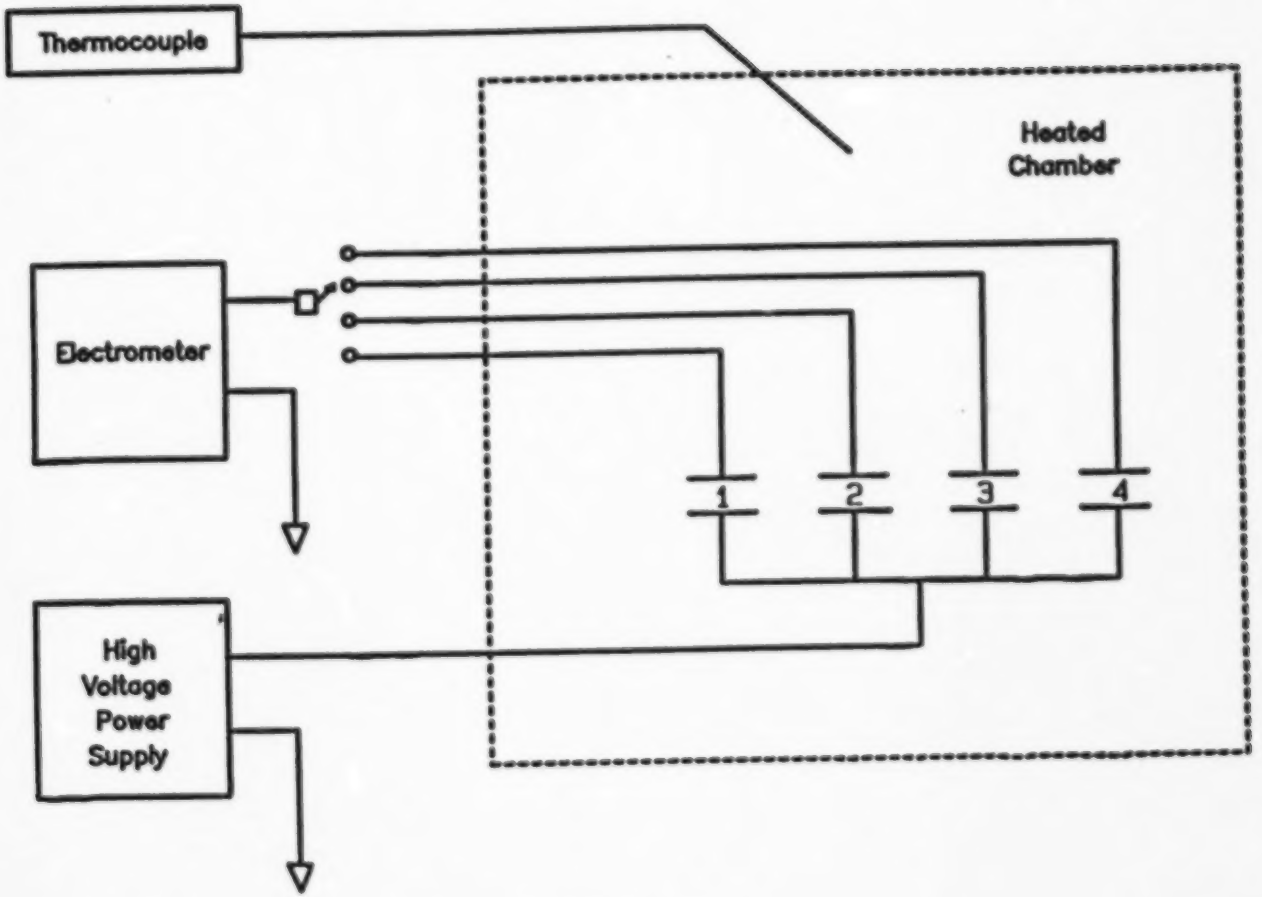

Figure 1. Diagram of the resistivity apparatus.

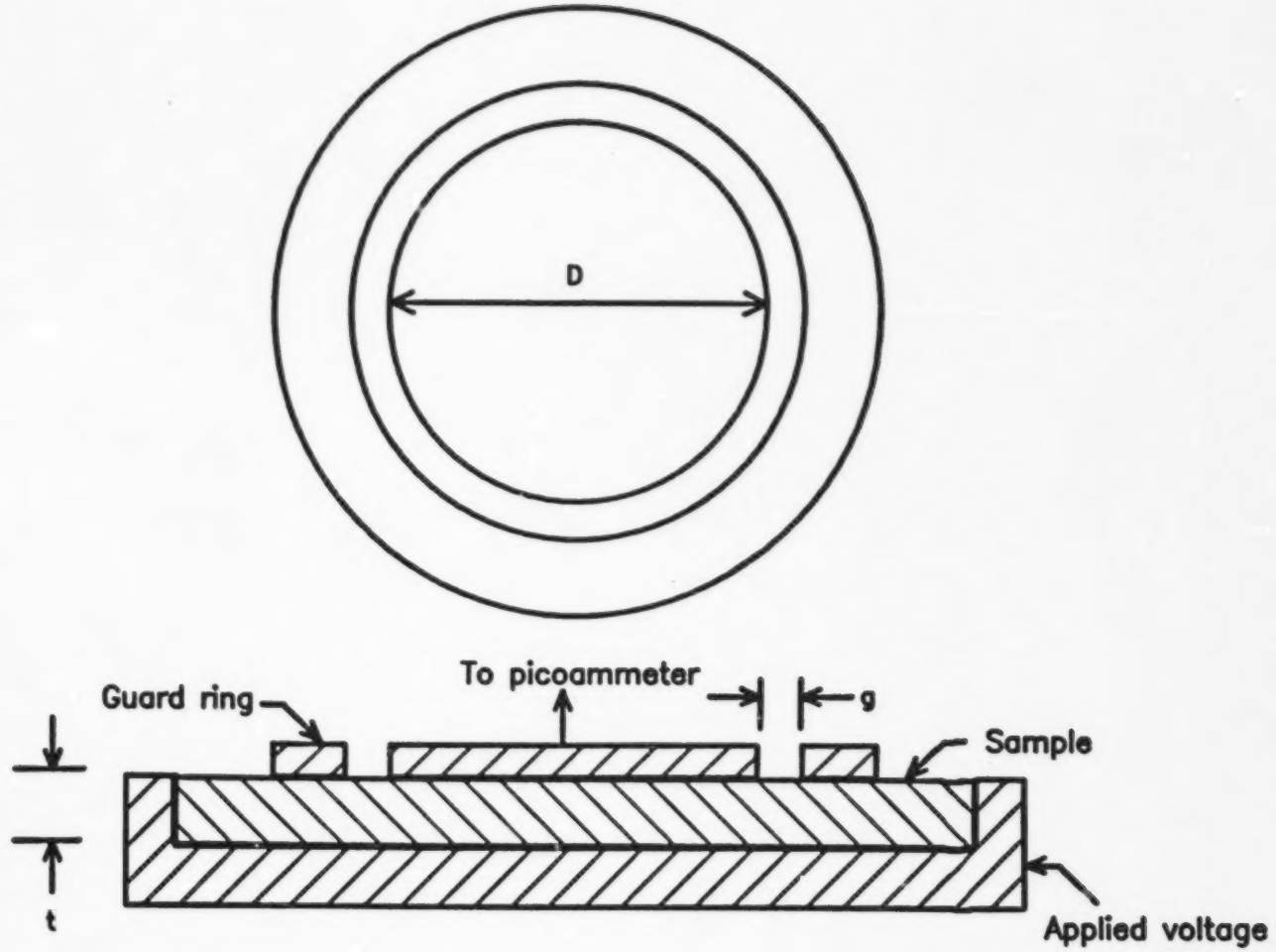

Figure 2. Resistivity sample cell.

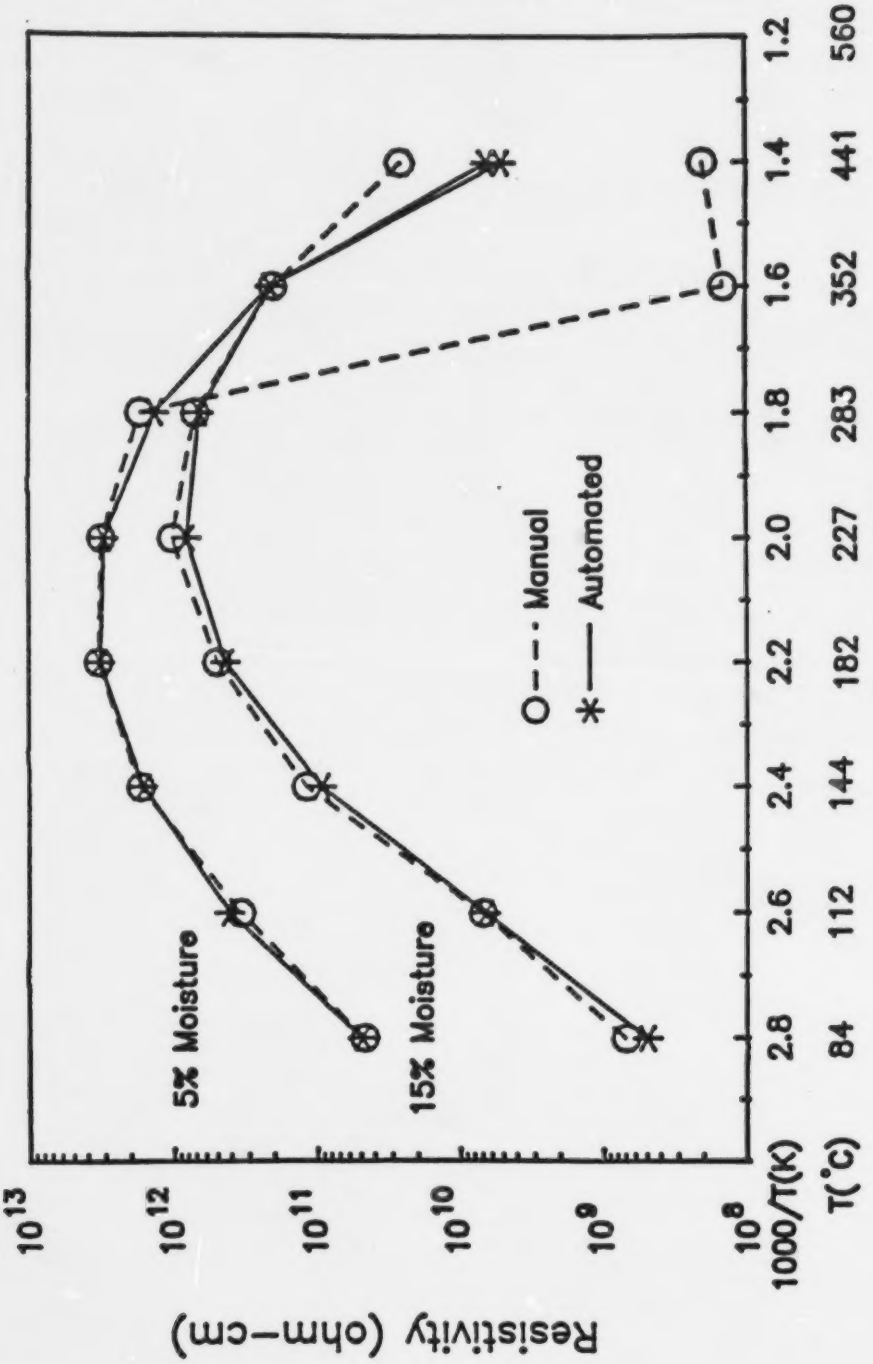

Figure 3. Comparison of automated and manual data for fly ash No. 1.

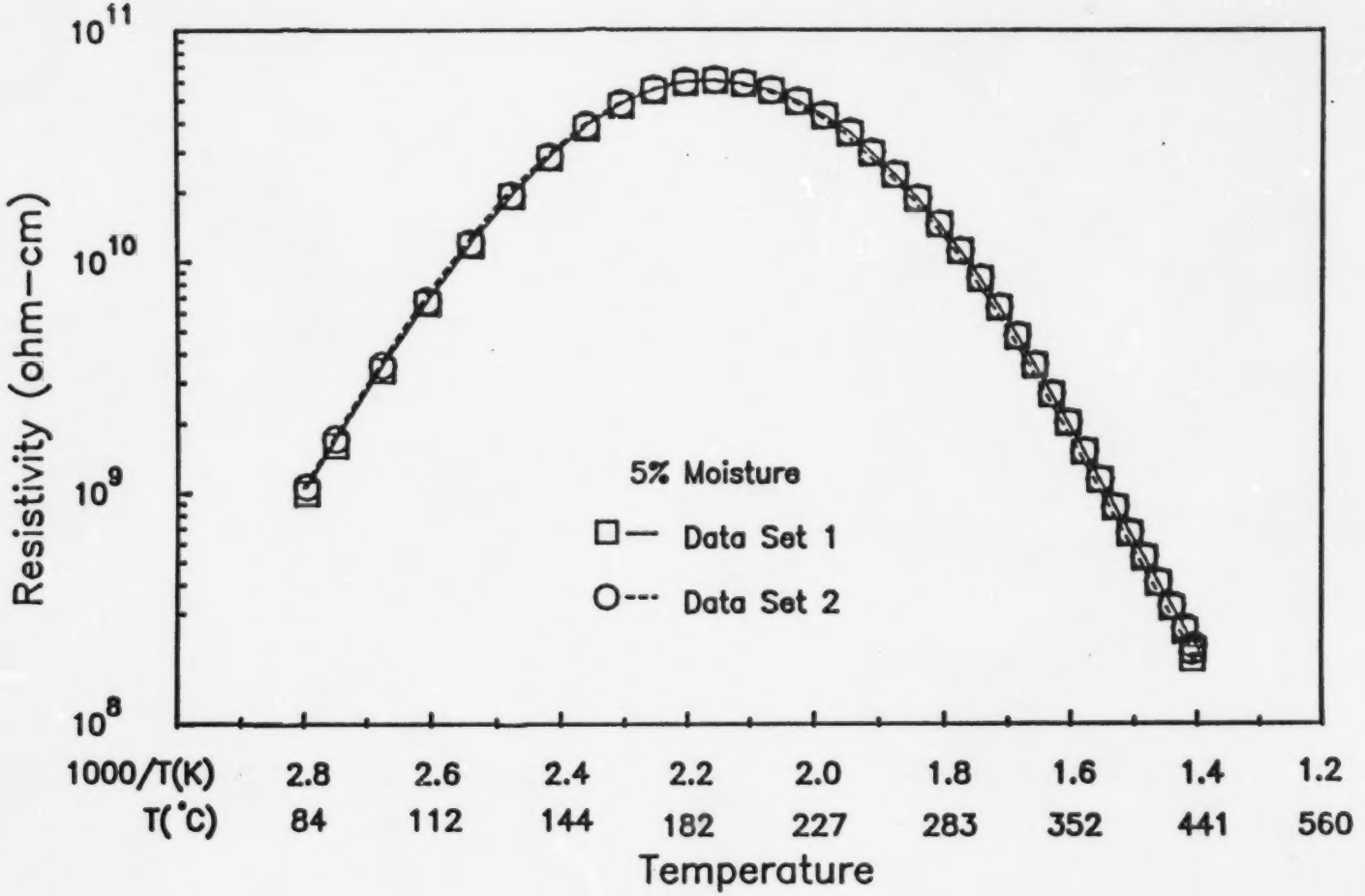

Figure 4. Demonstration of test precision for fly ash No. 2.